Replication of Heart Rate Variability Provocation Study with 2.4 GHz Cordless Phone Confirms Original Findings

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ABSTRACT**:** This is a replication of a study that we previously conducted in Colorado with 25 subjects designed to test the effect of electromagnetic radiation generated by the base station of a cordless phone on heart rate variability (HRV). In the current study we analyzed the response of 69 subjects between the ages of 26 and 80 in both Canada and the United States. Subjects were exposed for 3-minute intervals to radiation generated by a 2.4 GHz cordless phone base station (3–8 $\mu W/cm^2$). A few participants had a severe reaction to the radiation with an increase in heart rate and altered HRV indicative of an alarm response to stress. Based on the HRV analyses of the 69 subjects, 7% were classified as being "moderately to very" sensitive, 29% were "little to moderately" sensitive, 30% were "not to little" sensitive and 6% were "unknown." These results are not psychosomatic and are not due to electromagnetic interference. Twenty-five percent of the subjects' self-proclaimed sensitivity corresponded to that based on the HRV analysis, while 32% over-estimated their senstiivity and 42% did not know whether or not they were electrically sensitive. Of the 39 participants who claimed to experience some electrical hypersensitivity, 36% claimed they also reacted to a cordless phone and experienced heart symptoms and, of these, 64% were classified as having some degree of EHS based on their HRV response. Novel findings include documentation of a delayed response to radiation. Orthostatic HRV testing combined with provocation testing may provide a diagnostic tool for some sufferers of electrohypersensitivity (EHS) when they are exposed to electromagnetic emitting devices. The protocol used underestimates reaction to electromagnetic radiation for those who have a delayed autonomic nervous system reaction and it may under diagnose those who have adrenal exhaustion as their ability to mount a response to a stressor is diminished.

Key words

heart rate variability, HRV, cordless phone, mobile phone, tachycardia, arrhythmia, microwave radiation, 2.4 GHz, radio frequency radiation, electrohypersensitivity, electrical sensitivity, autonomic nervous system, nerve express, parasympathetic nervous system, sympathetic nervous system

Introduction

Individuals who complain of electrical hypersensitivity experience a myriad of symptoms that may include heart palpitation, arrhythmia, tachycardia, pain or pressure in the chest that may or may not be acccompained by anxiety, dizziness, nausea, and headaches [1-5]. Since we have technology to measure the activity of the heart and the autonomic nervous system (ANS), monitoring the effect of electromagnetic radiation (EMR) on the heart is relatively straight forward.

In 2010 we published a proof-of-concept study [6] that asked a basic questions, "*Does the microwave radiation (2.4 GHz) from a cordless phone affect the heart?*" A cordless phone base station[1] was selected for this provocation because it emits pulsed microwave radiation when the base station is plugged into an electrical outlet, and–unlike a cell phone–subjects are not required to talk and hence there is less human activity that may interfere with heart rate (HR) and heart rate variability (HRV). Andrzejak et al. [7] tested the effect of mobile phones on HRV in healthy volunteers and they observed a change in the autonomic balance with an increase in the parasympathetic nervous system (PNS) and a decrease in the sympathetic nervous system (SNS), but they could not rule out the effect of talking on the phone.

[1] The base for a cordless phone is referred to as the *base station*. With multiple hand-sets the primary base is the base station and the rest are satellite stations.

In our proof-of-concept study 10 out of 25 subjects (40%) in Colorado responded to the electromagnetic radiation (EMR) generated by the cordless phone. In these subjects, response and recovery were immediate. The common responses documented were an increase in heart rate (tachycardia), up regulation of the SNS and down regulation of the PNS similar to a *fight-or-flight* stress response. The severe and moderate responders had a much higher LF/HF[2] ratio (SNS/PNS) than those who either did not respond or had a mild reaction to the EMR exposure from the cordless phone.

We repeated this study with an additional 75 subjects from Canada and the United States and provide the HRV results here. The analysis of the wellness questionnaire is provided elsewhere [8].

Primer on Heart Rate Variability and the Autonomic Nervous System (ANS) based on Nerve Express

The Nerve Express technology, develped by Alexander Riftine, provides a quantitative assessment of the ANS based on HRV. The theoretical basis and clinical use are available [9] and only a brief description will be provided here to make the content easier to understand, since some graphics are specific to Nerve Express.

Orthostatic testing

Rhythmograph: Orthostatic testing is done to determine the response of the ANS to mild stress experienced when a person moves from a supine (lying down) to an upright (standing) position. This test is based on the time intervals between the R-R beats of the heart over a period of 448 beats (frequency interval) and is demonstrated as a rhymograph. Figure 1 provides examples for 4 different conditions.

A healthy and physically fit person (Fig. 1a) has high HRV–as shown by the regular undulations; a sharp decrease (elevated heart rate) and rapid recovery in the R-R interval during the transition phase (beats 192 to 256). The heart rate is generally low and increases marginally with exertion.

An unhealthy person with poor physical fitness (Fig. 1b) has a flat rhythmograph (low variability); a shallow dip during transition to standing; and an elevated heart rate with and without exertion.

Atrial fibrillation (Fig. 1c), the most common cardiac arrhythmia, is shown by the multiple spikes or extra systoles, which are extra contractions of the heart that interrupt the normal regular rhythm of the heart. They occur when there is electrical discharge from somewhere in the heart other than the sino-atrial node.

Intermittent tachycardia (Fig. 1d) is represented by the sudden decrease in the R-R Interval, which indicates a faster heart rate. In this case the heart rate increased from 59 to more than 120 beats per minute while the person was lying down and remained elevated for the duration of the test period.

Sympathetic Nervous System (SNS) vs Parasympathetic Nervous System (PNS): Changes in the SNS (fight-or-flight) and the PNS (rest-and-digest) as one moves from a supine to an upright position are shown in Fig. 2. How the body regulates the SNS/PNS can provide valuable information on the relative health of the ANS and based on the direction and magnitude of the response can indicate chronic or temporary dysfunction, pathology, and degeneration.

Just as a stressor or physical activity can increase the ratio of SNS to PNS, eating a large meal immediately before HRV testing can also alter this ratio but in the opposite direction making a person feel tired or sleepy. This postprandial somnolence (sleepiness following a meal) has two components:

(1) parasympathetic upregulation, in response to food in the stomach and small intestine, combined with sympathetic down regulation shifts the body into a "rest and digest" state; and

(2) hormonal and neurochemical changes associated with glucose metabolism and insulin secretion. For this reason it is important to standardize when, how much, and the type of food consumed prior to testing or, if this is not possible, to record time since last meal was consumed.

Fitness and Adaptability: The physical fitness score (Fig. 3) is a combination of the short-term state of the physiological system (1-13, horizontal axis), which can change quickly and is a reflection of how well rested the person is; and the long-term adaptability of the system (1-7, horizontal axis), which changes more slowly. Top athletes rank in the blue zone (top left corner) and those who are chronically ill in the red zone (bottom right). Healthy individuals fall within the green zone and their relative fitness is a function of how close they are to the two extremes.

[2] LF/HF ratio is commonly used to assess HRV responses. LF refers to low frequency and HF to high frequency associated with SNS and PNS respectively. A high LF/HF ratio is indicative of SNS dominance.

Real-Time Monitoring

During real-time monitoring, stages can be set for data analysis that are based on a pre-determined number of heart beats (frequency interval). In the current study we set the stage length (or refresh rate) to 192 R-R intervals (approximately 3 minute duration depending on heart rate). Data provided include HR, HF, LF1, LF2, SNS and PNS in a table. The latter two are also provided graphically and the R-R interval is presented as a rhymograph (Fig. 4).

Definition of terms and acronyms:

- HR – heart rate (beats per minute);
- HF – high frequency variations (0.15 and 0.5 Hz) are highly correlated with the activity of the parasympathetic nervous system;
- LF – low frequency variations (0.04 to 0.15 Hz) are used to assess activity of the sympathetic nervous system although these are not as precise as for HF; the low frequency bandwidth is further divided into LF1 (reflects adrenergic and cholinergic response) and LF2 (reflects changes in baroreceptors, also kown as the Mayer waves below 0.1 Hz or 10-second waves).
- SNS – sympathetic nervous system regulates the “fight or flight” response resulting in an increase in heart rate in preparation for activity.
- PNS – parasympathetic nervous system regulates the “rest & digest” response and counter balances the SNS by bringing the heart back to a resting state once the “stressor” is no longer present or the activity is reduced.

Material and Methods

This was a double-blind, sham controlled study. The same recruiting method and the same testing protocol for measuring the electromagnetic environment, for monitoring HRV were followed as in the previous study and are provided elsewhere [6]. Only situations specific to this study and related to the functioning of the ANS are provided here. The wellness questionnaire data are published elsewhere [8].

In this study we tested 75 subjects in six locations during the period October 23, 2008 to March 1, 2009. Testing was done in either a private home or doctor’s office in five U.S. cities (San Francisco, California; Tucson, Arizona; Santa Fe, New Mexico; Taylor, Wisconsin; and New York, New York) and one Canadian city (Simcoe, Ontario). Steps were taken to ensure that testing was done in an electromagnetically clean environment with low background values for magnetic fields, dirty electricity, and radio frequency radiation. GS filters were installed where needed to improve power quality (reduce dirty electricity). All other exposures were naturally low. The background values for each environment are provided in TABLE I.

Results and Discussion

Electromagnetic Exposure in Test Environment

Environments were selected for low background levels of anthropogenic electromagnetic exposure (TABLE I). Extremely low frequency magnetic fields (ELF MF) ranged from 0.2 mG (Taylor, WI) to 1.5 mG (New York, NY). Power quality was between 30 GS[3] units (San Francisco, CA) and 109 GS units (New York, NY). Radio frequency radiation was undetected (less than 0.004 $\mu W/cm^2$) in all but two environments where levels were low (0.01 to 0.05 $\mu W/cm^2$ in Tucson and New York respectively).

The radiation generated by the cordless phone was between 3 and 8 $\mu W/cm^2$ at the closest body part (head) of each test subject while subject was lying down during the provocation portion of this study. Exposures (real and sham) were for periods of approximately 3-minutes and were randomized. Neither the subject nor the doctor (JM) analyzing the HRV data knew when subjects were exposed. Radiation from the cordless phone base station was 100 to 1000 times higher than background levels in the test environments and was considerably lower than the guidelines recommended by ICNIRP (International Commission for Non-Ionizing Radiation Protection) for 2.4 GHz radiation of 1000 $\mu W/cm^2$. Maximum exposure to radiation from the cordless phone was at 0.8% of ICNIRP guidelines. The guidelines are the same in Canada and the United States, although in Canada public exposure is averaged over a 6-minute period and in the United States over a 30-minute period. Neither country has long-term exposure guidelines. Note also that these guidelines are based on a thermal effect of increasing body temperature. They do not consider more subtle effects such as changes in cardiac function.

[3] GS refers to the Graham Stetzer unit of measuring the energy associated with high frequency transients between 4 and 150 kHz on electrical wiring.

Test Subjects

Participants ranged in age from 26 to 80 with 82% between the ages of 40 to 70; most were female (73%). Additional information is provided elsewhere [8]. The data for seven participants were not included in the final HRV analysis: one had atrial fibrilation that prevented accurate analysis (Fig. 1C); another experience episodic tachycardia that was not related to exposure (Fig. 1D); and either missing data or compromised testing protocol eliminated the remaining five. The HRV analysis is based on a total of 69 participants.

Assessment of EHS Status

Determining whether or not a subject is "responding" to provocation is fairly straight forward in those subjects who mount a significant response during or immediately after exposure to the radiation through changes in the rhymograph, heart rate and/or the relative ratio of sympathetic to parasympathetic tone. It is also obvious in those who are "non-responders" (no significant change in any parameter tested).

Determining whether or not a *responder* or a *non-responder* has EHS, however, is not as straight forward. In the current study, the intensity of the response and the number of parameters that were altered during or after exposure contributed to the EHS classification with more intense reactions labeled "very sensitive".

For example, 44 (64%) of the subjects tested experienced fatigue and adrenal exhaustion based on the fitness results and the chronotropic reaction (orthostatic test). Someone with adrenal exhaustion has limited ability to mount a response to a stressor and, consequently, s/he could be mistaken for someone who is not electrically sensitive.

Examples of two *non-responders* are provided in Fig. 5 and 6. Subject in Fig. 5 was healthy and fit and did not respond immediately to the exposure and, consequently, he was classified as not sensitive. Subject in Fig. 6 had dysautonomia and adrenal exhaustion and probably had limited energy to mount a response. For this reason it was not possible to determine his EHS status. Because of this distinction the orthostatic test is essential to assess the baseline response for each subject and to compare their monitoring results to the degree of stress experienced when standing up.

Examples of *reactive* subjects are provided in Fig. 7, 8, and 9. Subject in Fig.7 had sufficient energy to mount a response as can be seen in the rhymograph (irregularity), the sympathetic and parasympathetic increase and changes in HF, LF1 and LF2. This subject was classified as moderately sensitive. Subject in Fig. 8 had exhausted adrenals and was able to mount a signficant response during the first exposure but not during subsequent exposures. He was classified as "very" sensitive. Subject with moderate fatigue (Fig. 9) was able to mount a response during both sets of exposures. An up regulation of the SNS combined with a down regulation of the PNS is a typical alarm– "fight or flight"–reaction.

One of the test subjects mentioned that he normally responds to electromagnetic exposure with a delay of 10 minutes or more, so we extended the monitoring time post-exposure by approximately 30 minutes (Fig. 10). Subject 28 began to respond post-exposure at stage 7 and the fluctuations in the rhymograph and in SNS and PNS become increasingly common over time. Based on the delayed response this subject was classified as very sensitive. His sensitivity would have been missed had the monitoring period lasted only a few minutes. This points out one of the major weakness of a study that is so short, namely that a delayed response will be missed.

One way to improve the quality of data collection is to extend duration for the background condition, sham exposure, direct exposure and post–exposure and to reduce the sampling period (refresh rate) from 192 to 48 heart beats (R-R intervals).

Electromagnetic Interference (EMI)

Electromagnetic interference (EMI) with test equipment has been suggested in the non-peer reviewed literature as a possible explanation for the altered HRV parameters that we documented in our first study [6]. To test this hypothesis we repeated exposure with a blinded subject who was healthy and non-reactive and moved the radiation source from the head to the heart. This increased exposure from 2 to 100–200 $\mu W/cm^2$ at both the heart and the receiver. These levels are still below the thermal guidelines of 1000 $\mu W/cm^2$. The only change documented was a slight and temporary decrease in the PNS [8]. It is worth noting that had EMI been involved then all of the exposures would have interfered with the technology since the identical protocol was used for all testing. Furthermore, EMI can not explain the delayed reaction after the radiation was discontinued (Fig. 10).

Provocation HRV

Of the 69 participants, 46 participants were **classified** (by JM) as "little to very" EHS. Of these, 18 (39%) did not know whether or not they had EHS, one (2%) believed he was not sensitive, and 27 (39%) believed they were sensitive (Table II). Indeed there was agreement with the degree of sensitivity (little to very) for 17 (25%) of the subjects. This relatively high percentage showing a convergence of assessment is not in agreement with the reviews on this subject conducted by a psychologist who believes that EHS is psychosomatic rather than a physical response [9, 10, 11].

Of the 69 participants, 39 (57%) were **self-proclaimed electrosensitives**; 29 (42%) stated they reacted to a cordless phone (sometimes to always); and 22 (32%) experienced some heart-related symptoms that could be detected by the HRV analysis (altered heart rate and/or arrythemia). Only 14 participants (20%) claimed they experienced all three simulateously. Of these 14 subjects, 9 were classified as being "little to very" EHS based on their HRV results.

In a questionnaire study in the Netherlands, when asked "which appliances are bothering you the most?" the DECT phone was at the top of the list with 38% of the 189 respondents [12]. The difference between a DECT phone and the cordless phone we used in this study is the carrier frequency. DECT phones operate at 1.9 GHz and the cordless phone in this study was at 2.4 GHz. Both fall within the microwave band of the electromagnetic spectrum.

In the study mentioned above [12], heart rhythm problems were experienced by 17% of the respondents and changed blood pressure by 10%. Chronic fatigue was one of the most frequently cited health problems with 70% of the 250 respondents complaining of this illness. Fatigue was also observed in a large percentage of subjects in the current study and this may be a result of continuous exposure resulting in chronic stress leading to adrenal exhaution. An alternative explanation is those who are chronically tired, for whatever reason, are more sensitive to an additional stressor on the body.

Laboratory studies with humans and rats provide similar and complementary results.

Albino rats were exposed to radiation emitted by a mobile phone for 1, 2, or 3 hours daily for either 4 or 8 weeks [13]. A number of effects were documented including: an increase in systolic blood pressure; a decrease in heart rate in the longest exposures; increased QRS duration (QRS refering to a portion of the ECG tracing of the heart) in all 8-week exposures; increase in heart weight and weight of the left ventrical; increased plasma renin activity (which plays a role in blood pressure); a decrease in plasma calcium levels; a decrease in plasma total anti-oxidant levels; as well as hypertrophy, fragmentation and vacuolation of the heart muscle that was directly proportional to exposure time. These results indicate damage to the heart muscle with prolonged exposure to microwave radiation emitted by a mobile phone.

A female physician who diagnosed herself with EMF hypersensitivity was exposed under controlled conditions in a double-blind provocation study to 60 Hz, 300 V/m electric fields [14]. She experienced temporal pain, headache, muscle twitching and skipped heart beats 100 seconds after initiation of EMF exposure ($P<0.05$) and her responses was primarily to field transitions (on-off switching) during which time high frequency (radio frequency) transients are sent along electrical wires. She had no conscious perception of the field but did experience a reliable somatic reaction. The authors conclude that "EMF hypersensitivity can occur as a bona fide enviornmentally inducible neurological syndrome."

Why is it that some studies do not show a response to exposure? The symptoms associated with exposure are quite complex, and unlike turning on a light switch and getting light each time, the body has an internal homeostatic system that tries to maintain a healthy equilibrium. The functioning of the autonomic nervous system is non-linear and, as such, difficult to predict.

Bevington [2] identifies some key parameters that need to be considered when conducting provocation studies.

- *Accumulation*: Cumulative exposures can produce symptoms, making symptoms from chronic exposure more difficult to recognize than from acute exposure.
- *Delay*: Symptoms can be delayed after acute exposure for a few hours or even days. This is said to become more common the longer the patient has been sensitized.
- *Diurnal state*: Symptoms vary according to the diurnal state of the person's body. A person's own endogenous electromagnetic field often declines during the day.
- *Duration*: Individual symptoms can last for a short or long time. As a group symptoms can become worse. They can fade after 2-12 months without EMR exposure.
- *Frequencies*: The sufferer may react first to a single frequency or source but later to more (e.g. first to Wi-Fi but later to mobile phones and power cables).
- *Intensity*: As the condition progresses the level of sensitivity can increase; a person may first have pains from a phone next to the head but later from one at 3 m.
- *Variations*: Individual variations in tissue/bone density, acidity, salt content, skin conductivity, size etc. affect absorption. This may relate to the variety of symptoms.

Subjects have varied reactions to radio frequency exposure at levels that are well within international guidelines as recommended by ICNIRP and guidelines in both Canada and the United States (currently 1000 $\mu W/cm^2$ for microwave frequencies at 2.4 GHz). For some the reaction is immediate, for others it is delayed, and for some it is prolonged well beyond exposure. The protocol we used in this study is likely to underestimate sensitivity or reactivity to radio frequency radiation. This protocol can be modified to take into account delayed responders and needs to be modified to improve the quality of the data collection for each subject. For those wanting to repeat or conduct a similar study we would recommend the following for real time monitoring:

1. Important to wait until the autonomic nervous system (PNS and SNS) has stabilized before exposure or sham exposure begins. This can be done by monitoring heart rate while the person is lying down. Their resting heart rate and SNS, PNS response should be similar to their supine orthostatic readings.
2. Important to allow for longer exposure periods and longer periods of sham and post exposure than 3 minutes since there can be a delayed reaction.
3. Since subjects can react quickly to this type of provocation, reducing the assessment period (refresh rate) from 192 to 48 heart beats (R-R intervals) for the same or longer time period would enable a more accurate and detailed assessment.

The concept that microwave radiation may affect the heart is not new. In a 1969 Symposium Proceedings–under the auspices of the U.S. Department of Health, Education, and Welfare–on the Biological Effects and Health Implications of Microwave Radiation [15], scientists recognized the adverse effects on the cardiovascular system and recommend that cardiovascular abnormalities be used as screening criteria to exclude people from occupations involving radio frequency exposures. That warning has not been heeded and indeed, microwave transmitters (mobile phones, Wi-Fi routers, wireless baby monitors, wireless computer games, smart meters, etc.) are now commonly used in homes, schools, work environments as well as in hospitals and doctors clinics. If our results are real and if exposure continues to increase we are likely to observe an increase in heart-related problems among younger people and among those whose immune system is compromised.

Conclusion

Our results show that a considerable percentage of the individuals tested were moderately to very sensitive to radiation generated by a cordless phone based on HRV and that their reactions were not psychosomatic. In this double-blind, sham-controlled study, we document an increased heart rate, altered HRV, and changes in the sympathetic and parasympathetic control of the autonomic nervous system similar to our previous study. The results are not due to electromagnetic interference (EMI) since we have examples of a delayed response after the radiation was turned off and have tested EMI with much higher exposure using the same technology with no reactions noted. Our results demonstrate that the radiation from a 2.4 GHz cordless phone affects the autonomic nervous system and may put some individuals with pre-existing heart conditions at risk when exposed to electromagnetic frequencies to which they are sensitive. While documenting a response is relatively simple, determining the degree of EHS is quite complex and requires further study.

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MH has no conflict of interest. Bioenergimed Metabolic Institute sells medical products including the Nerve Express.

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Tables

TABLE I. MEASUREMENT OF THE ELECTROMAGNETIC ENVIRONMENT AT EACH TESTING LOCATION.

Location	Date of Testing	Subjects Tested	Background Levels: Magnetic Field	Dirty Electricity	Radio Frequency
		#	mG	GS units	$\mu W/cm^2$
San Francisco, CA	23–24 Oct 2008	21	0.5	30	<0.004
Simcoe, ON	15 Nov 2008	7	0.4	60	<0.004
Taylor, WI	24 Nov 2008	10	0.2	48	<0.004
Tucson, AZ	20 Dec 2008	9	0.8	60	0.05
Santa Fe, NM	21 Dec 2008	11	0.6	42	<0.004
New York, NY	26 Feb – 1 Mar 2009	17	1.5	90-110	0.01

Table II. COMPARISON OF EHS STATUS BASED ON HRV ANALYSIS AND SELF-PROCLAMATIONS. DEGREE OF SENSITIVITY IS IDENTIFIED AS VERY (V) MODERATE (M), LITTLE (L), NOT (N), AND DON'T KNOW (?). THE AGREEMENT BETWEEN SELF DIAGNOSIS AND HRV ANALYSIS IS HIGH LIGHTED IN GREY (N=69).

EHS 27 (39%)	EHS based on HRV Analysis: MV	LM	NL	N	?	total	agreement
EHS self proclaimed: V	4 (6%)	3 (4%)	7 (10%)	6 (9%)	1 (1%)	21 (30%)	4 (6%)
M	0 (0%)	3 (4%)	2 (3%)	0 (0%)	1 (1%)	6 (9%)	3 (4%)
L	0 (0%)	4 (6%)	4 (6%)	4 (6%)	0 (0%)	12 (17%)	8 (12%)
N	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)
?	1 (1%)	9 (13%)	8 (12%)	9 (13%)	2 (3%)	29 (42%)	2 (3%)
total	5 (7%)	20 (29%)	21 (30%)	19 (28%)	4 (6%)	69 (100%)	17 (25%)
agreement	4 (6%)	7 (10%)	4 (6%)	0%	2 (3%)	17 (25%)	

Figures

Figure 1. Examples of the Nerve Express orthostatic rhythmograph for different conditions.

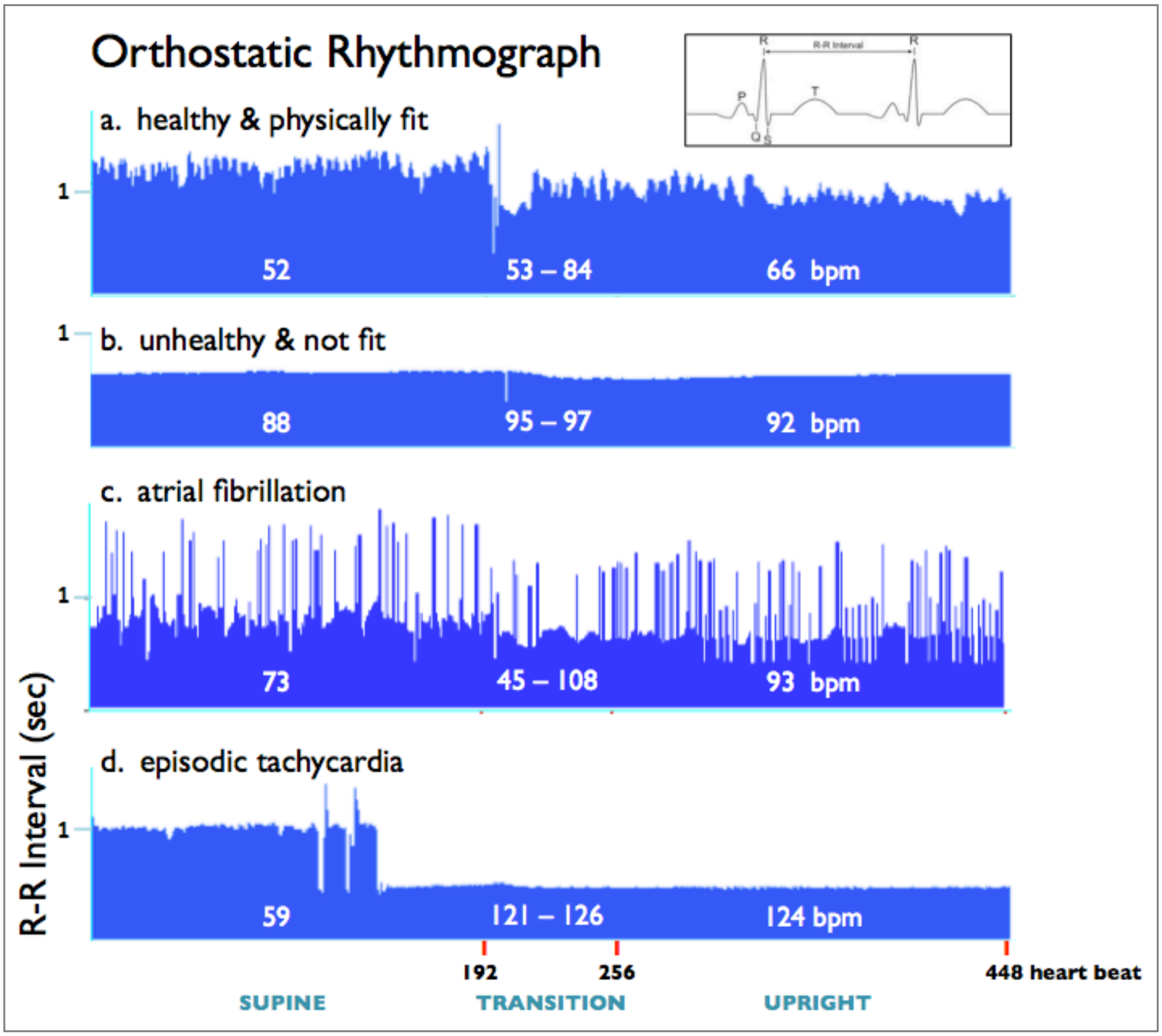


Figure 2. Interpretation of the ANS response for the orthostatic test. Based on Riftine [9].

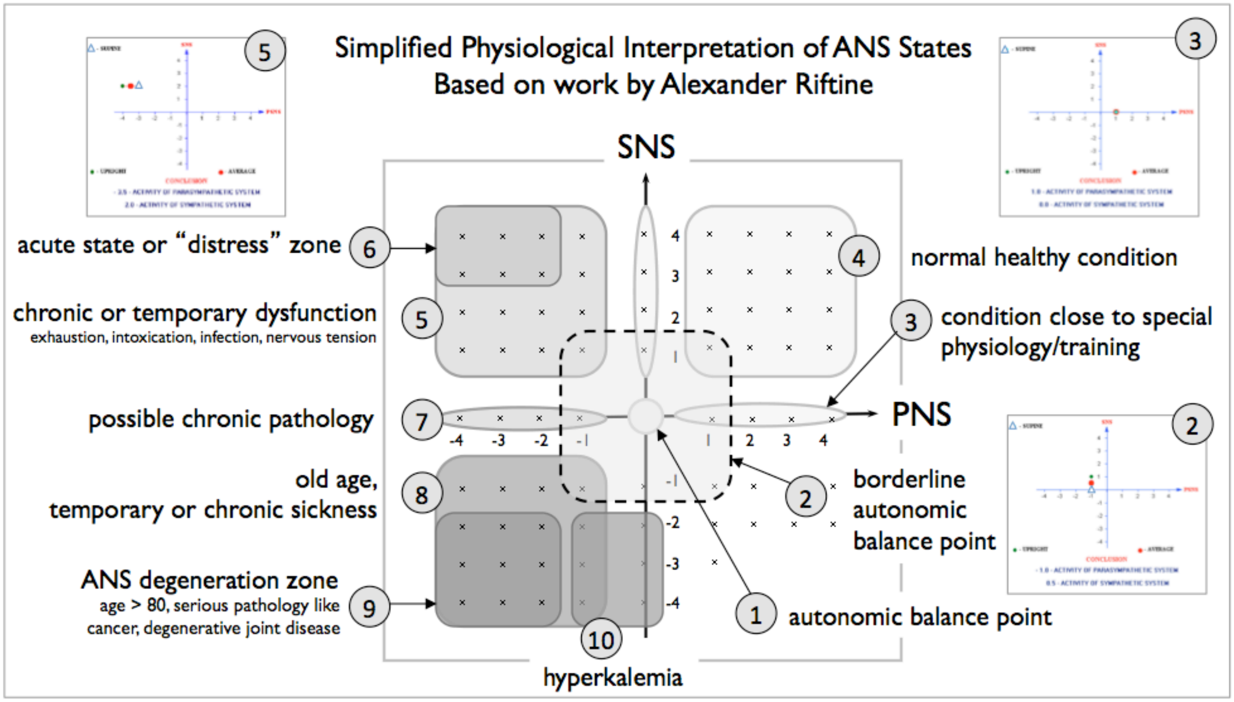


Figure 3. Physical fitness based on the orthostatic test. Fitness decreases as one approaches the lower right corner of the graph. A fitness score at and above 10 (horizontal axis) indicates fatigue. The relative fitness of the four examples decreases from A (6–1) to D (12–7).

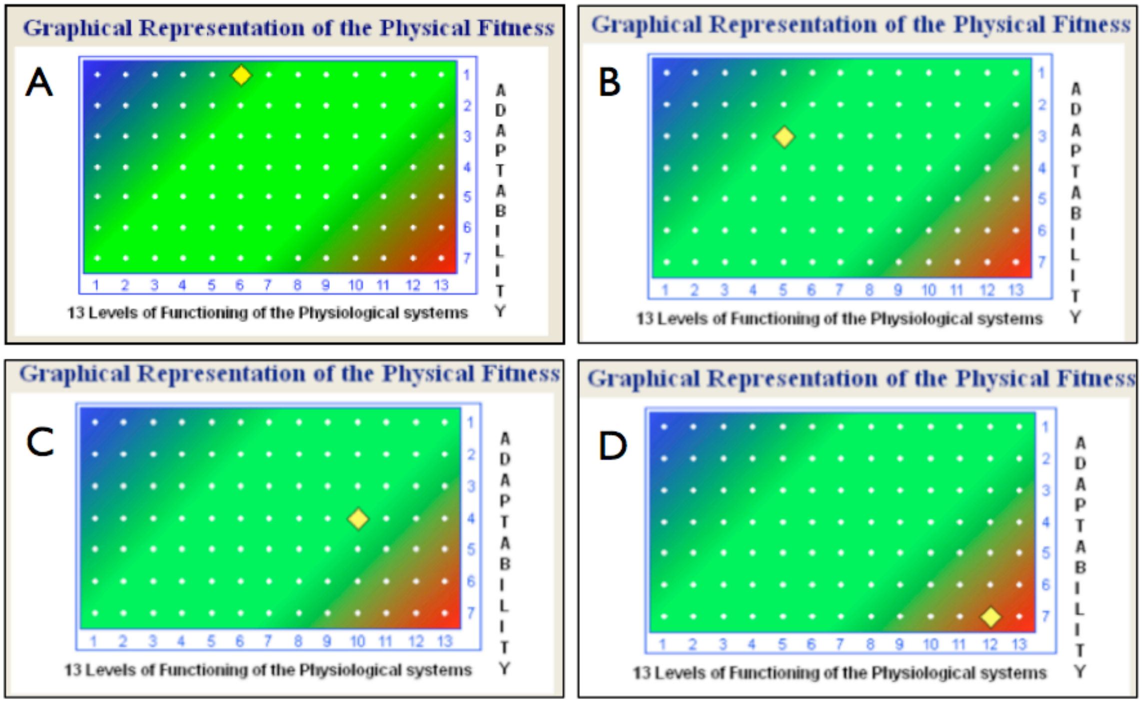
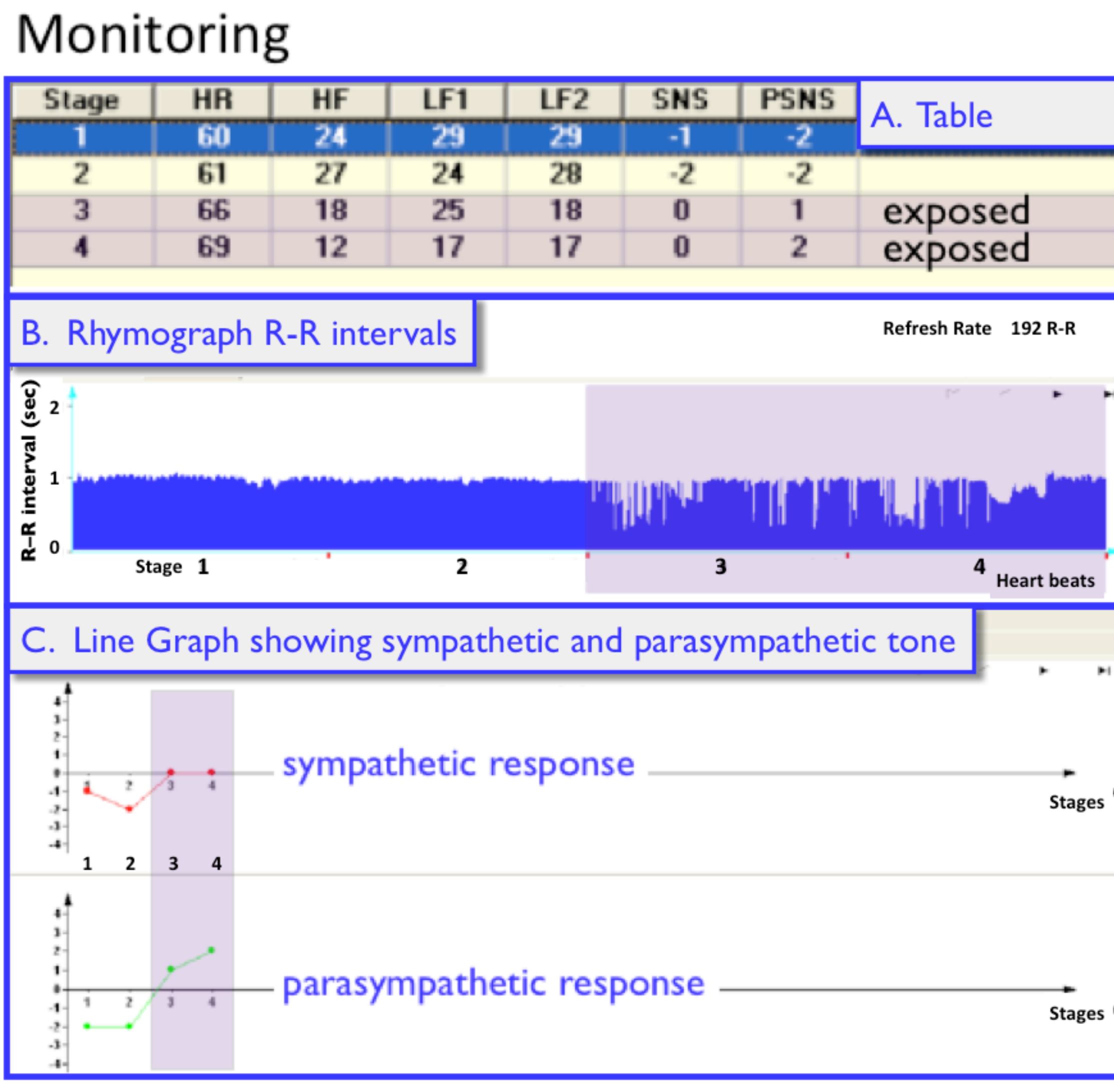


Figure 4. Real-time monitoring of exposure showing heart rate (HR), high frequency (HF), low frequency (LF1 and LF2), sympathetic nervous system (SNS), parasympathetic nervous system (PNS), and the time interval for the heart beats (R-R interval). The example provided shows expsoure during stages 3 and 4.


Monitoring
A. Table

Stage	HR	HF	LF1	LF2	SNS	PSNS	
1	60	24	29	29	-1	-2	
2	61	27	24	28	-2	-2	
3	66	18	25	18	0	1	exposed
4	69	12	17	17	0	2	exposed

B. Rhymograph R-R intervals
Refresh Rate 192 R-R
R-R interval (sec)
2
1
0
Stage 1
2
3
4
Heart beats
C. Line Graph showing sympathetic and parasympathetic tone
sympathetic response
Stages
1 2 3 4
parasympathetic response
Stages

Figure 5. HRV parameters for a **healthy subject** who is not responding to any exposure. This subject was classified as **not electrically sensitive** based on short-term exposure to the radiation generated by a cordless phone base station.

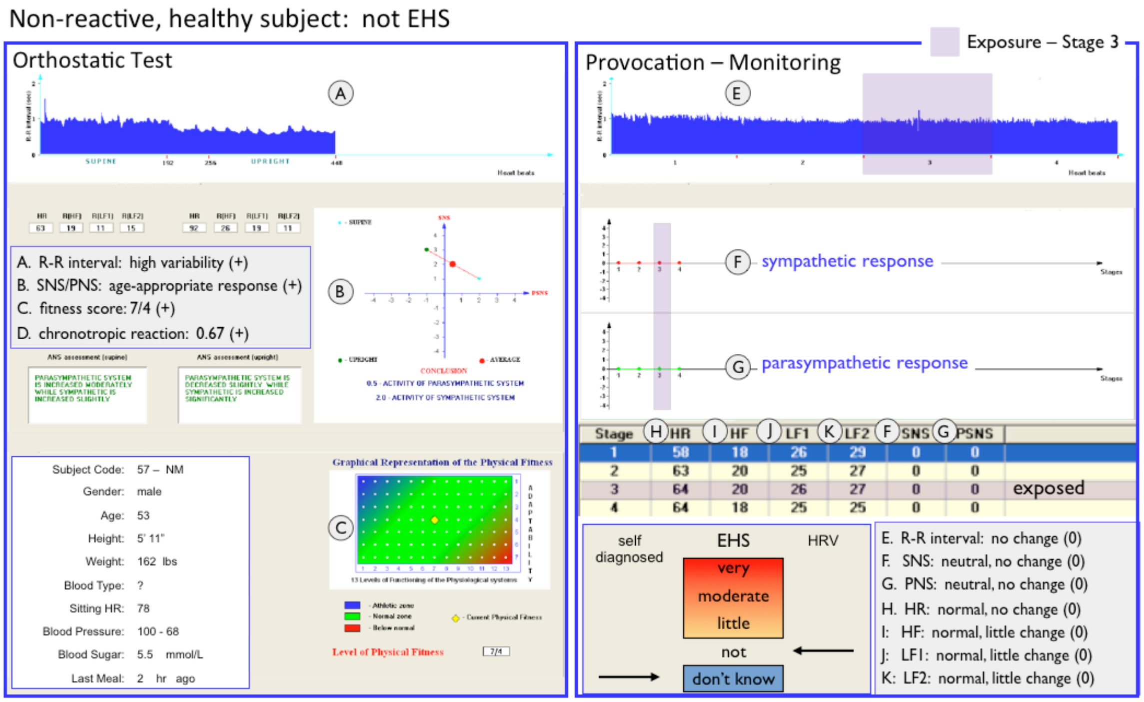


Figure 6. HRV parameters for a subject with **dysautonomia** and **adrenal exhaustion** who is not responding to any exposure. This subject's electrical hypersensitivity was classified as **unknown** due to adrenal exhaustion.

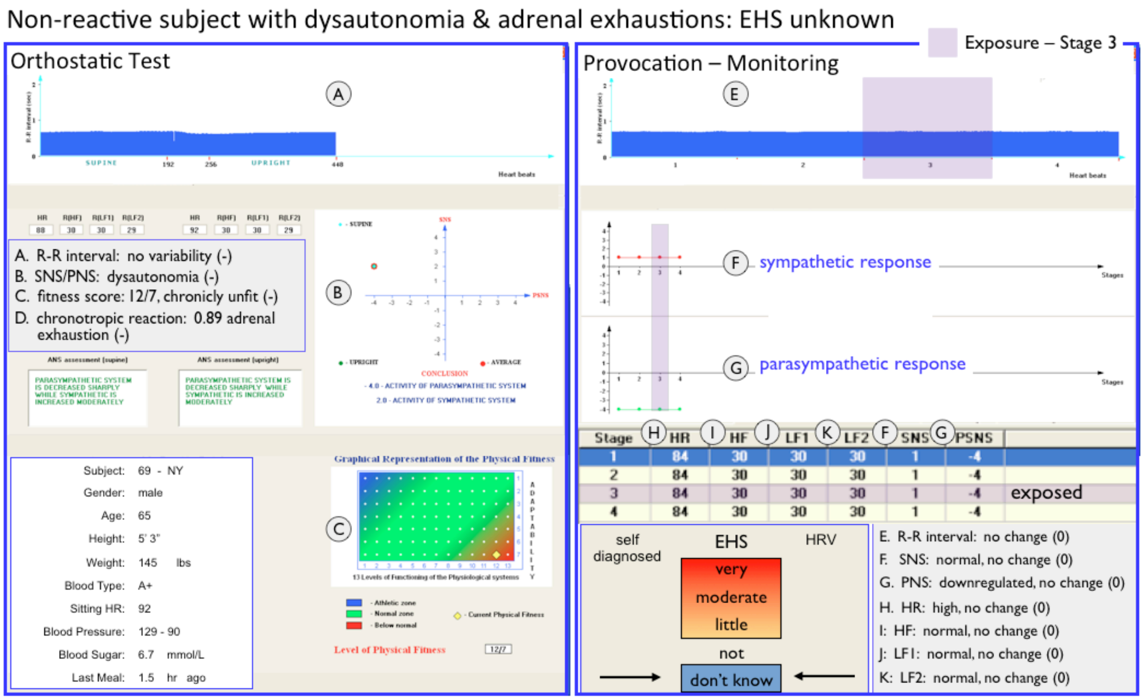


Figure 7. HRV parameters for a **healthy subject** with **moderate fatigue** who is reacting to the radiation generated by a cordless phone base station. This subject was classified as **moderately sensitive**.

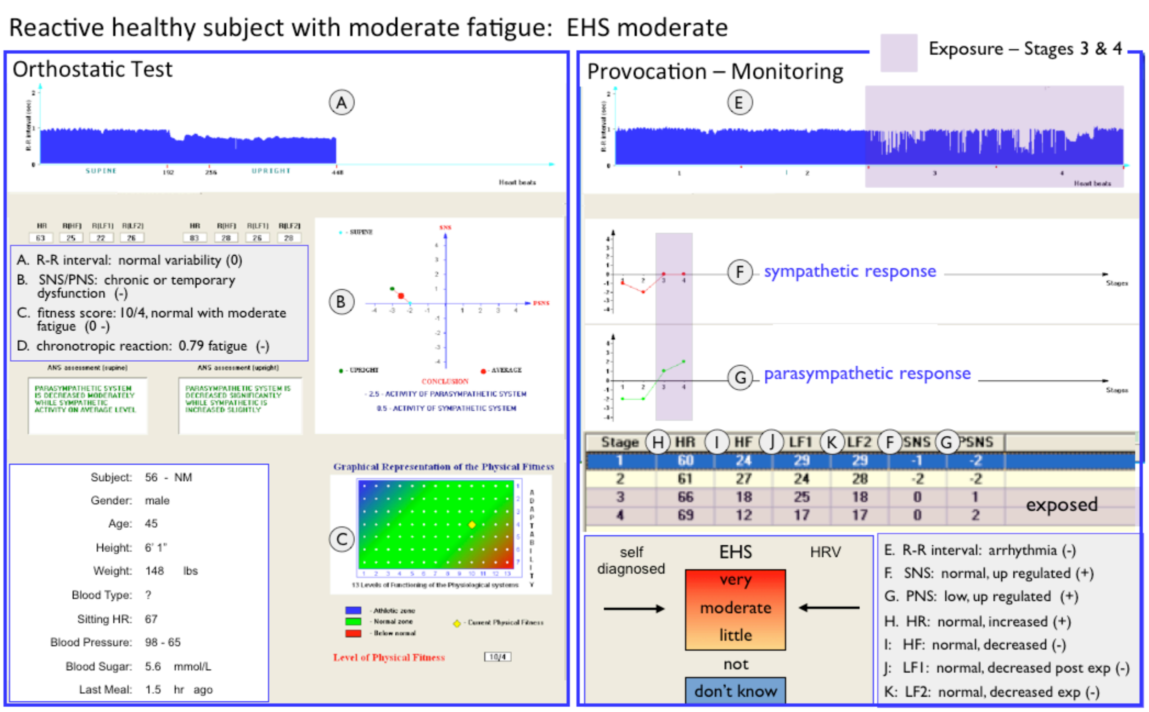


Figure 8. HRV parameters for a **healthy subject** with **adrenal exhaustion** who is reacting to the radiation generated by a cordless phone base station. This subject was classified as **very sensitive** due to tachycardia and sharp up regulation of both the SNS and PNS that is indicative of an alarm reaction. Subject responded primarily to first exposure perhaps due to adrenal exhaustion.

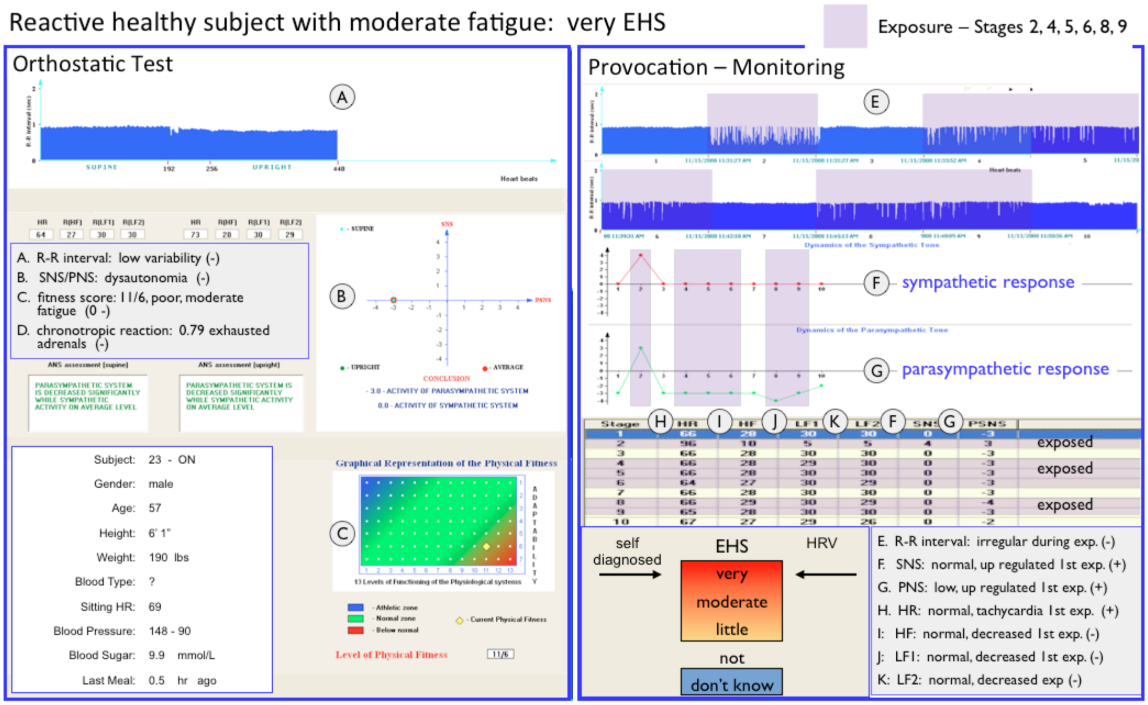


Figure 9. HRV parameters for a **healthy subject** with **moderate fatigue** who is reacting to the radiation generated by a cordless phone base station. This subject was classified as **very sensitive** due to tachycardia and sharp up regulation of both the SNS and PNS that are indicative of an alarm reaction. Subject reacted during all exposures.

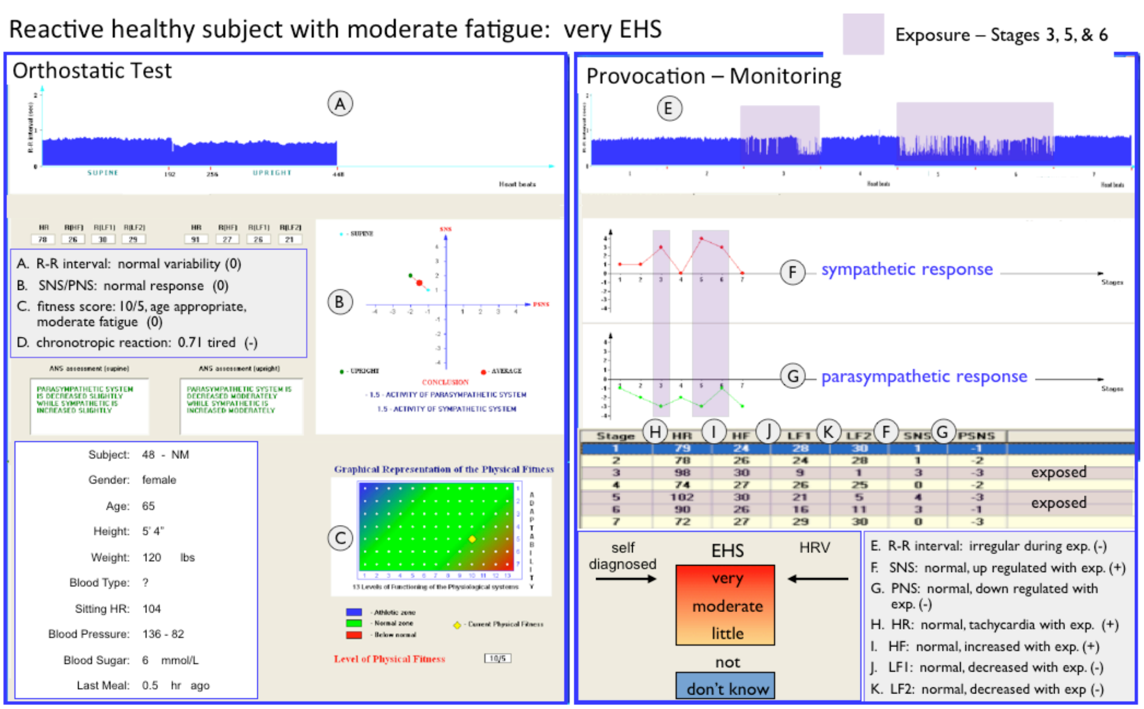
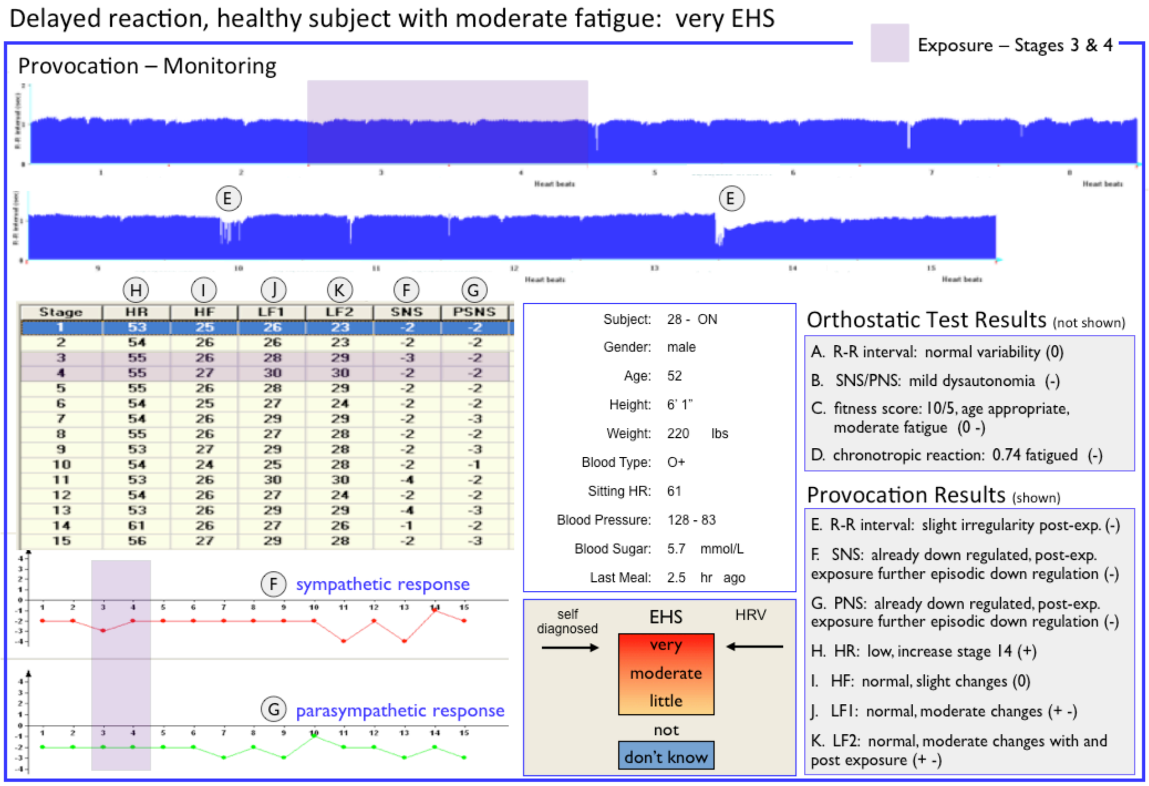


Figure 10. **Healthy** subject with **moderate fatigue** experienced a **delayed reaction** to radiation generated by a cordless phone base station. This subject was classified as being very sensitive.



Stage	HR	HF	LF1	LF2	SNS	PSNS
1	53	25	26	23	-2	-2
2	54	26	26	23	-2	-2
3	55	26	28	29	-3	-2
4	55	27	30	30	-2	-2
5	55	26	28	29	-2	-2
6	54	25	27	24	-2	-2
7	54	26	29	29	-2	-3
8	55	26	27	28	-2	-2
9	53	27	29	28	-2	-3
10	54	24	25	28	-2	-1
11	53	26	30	30	-4	-2
12	54	26	27	24	-2	-2
13	53	26	29	29	-4	-3
14	61	26	27	26	-1	-2
15	56	27	29	28	-2	-3